Faculty of Mechanical Engineering

ENERGY EFFICIENCY IN HEATING VENTILATION AIR CONDITIONING AND REFRIGERATION (HVAC & R) OPERATION THROUGH VARIABLE FREQUENCY DRIVE (VFD) APPLICATION

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DECLARATION

I declare that this thesis entitled "Energy Efficiency in Heating Ventilation Air Conditioning and Refrigeration (HVAC & R) Operation Through Variable Frequency Drive (VFD) Application" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : .....

Name : MOHD NAZRIN BIN NAHAR

Date : 25/3/2019

APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion, this dissertation/report is sufficient in terms of scope and quality as partial fulfillment of Master of Mechanical Engineering (Energy Engineering).

Signature : .....

Supervisor Name : DR. REDUAN BIN MAT DAN

Date : 27/03/2019

DEDICATION

For my beloved mother Azimah Binti Abdul Manaf, father Nahar Bin Haji Yaacob, wife Nur Atika Binti Roslan and children Muhammad Niyaz Akif and Maryam Nur Auni

ABSTRACTS

As the cost of energy is increasing, the understanding of energy efficiency and how it could be achieved is vital. Energy efficiency on Heating Ventilation Air Conditioning & Refrigeration (HVAC & R) system at the industries building is important in order to increase the understanding of particular topics involved in this research study. In order to reduce energy consumption for sustainable and energy efficient, an energy audit is needed to identify major energy problems in any condition areas at the building. It involves analyzing the actual consumption of electrical energy and measures energy conservation. Variable Frequency Drive (VFD) is a control device to regulate the speed and rotation force or output torque of mechanical equipment an alternating current (AC) by adjusting the frequency. The objective of this study is to verify the benefit of VFD in saving energy in the HVAC & R system, effectiveness of VFD throughout its service life and also to verify energy performance annually at the building and determine the changes between pre-retrofit and post-retrofit measurement for the building power consumption which can be declared as the energy savings. The research survey was conducted at GCH Fresh Distribution Centre in Kajang, Selangor. The study will discuss equipment system used and building modification, electrical rate system and the energy usage. Based on the analysis results and observations, some steps for reducing power consumption without affecting the comfort and satisfaction were recommended along with their cost analysis. The main focus of this research is on the electrical properties of both VFD application and without VFD (constant speed) application at the building. The analysis from data collection consists of power consumption (kWh), system current (A), system power (kW) and system volt amp (kVa) is clear that show the trend pattern of the saving using VFD application. By analyzing the energy consumption before and after the implementation of the retrofit, the effectiveness of the VFD in reducing energy consumption will be verified. Monitoring and Verification (M&V) plan for this building is proven it reduces operational HVAC & R costs by 7%.

ABSTRAK

Oleh kerana kos tenaga yang meningkat, sangat penting mengetahui tentang pemahaman mengenai kecekapan tenaga dan bagaimana ianya dapat dicapai. Kecekapan tenaga pada sistem pemanasan, pengudaraan, penyamanan udara dan penyejukbekuan (HVAC & R) di bangunan industri adalah sangat penting bagi meningkatkan pemahaman tentang topik tertentu yang terlibat dalam kajian ini. Bagi mengurangkan penggunaan tenaga yang mampan dan tenaga yang cekap, audit tenaga adalah diperlukan bagi mengenal pasti punca masalah tenaga yang utama di mana-mana keadaan kawasan di dalam bangunan. Ia melibatkan menganalisis penggunaan sebenar tenaga elektrik dan langkah-langkah pemuliharaan tenaga. Pemacu Frekuensi Pembolehubah (VFD) adalah alat kawalan yang mengawal kelajuan dan daya putaran atau tork keluaran pada peralatan mekanikal iaitu arus ulang alik (AC) dengan dilaraskan oleh frekuensi. Objektif kajian ini adalah untuk mengesahkan tentang faedah penggunaan VFD dalam menjimatkan tenaga pada sistem HVAC & R, keberkesanan jangka hayat servis VFD dan juga prestasi tenaga sepanjang tahun di dalam bangunan bagi menentukan perubahan antara pengukuran sebelum dan selepas pengubahsuaian untuk penggunaan kuasa di dalam bangunan yang boleh diisytiharkan sebagai penjimatan tenaga. Tinjauan penyelidikan telah dijalankan di GCH Pusat Pengedaran Segar di Kajang, Selangor. Penyelidikan yang dikaji adalah berkenaan sistem peralatan yang digunakan dan pengubahsuaian pada bangunan, kadar elektrik pada sistem dan penggunaan tenaga. Berdasarkan pemerhatian dan hasil analisa didapati beberapa langkah bagi mengurangkan penggunaan kuasa tenaga tanpa menjejaskan keselesaan dan kepuasan pengguna yang disyorkan seiring bersama dengan analisis kos. Fokus utama penyelidikan ini adalah sifat-sifat elektrik pada aplikasi VFD dan tanpa penggunaan VFD (kelajuan yang malar) di bangunan tersebut. Analisis yang diperolehi dari data tersebut terdiri daripada penggunaan kuasa (kWh), sistem arus (A), sistem kuasa (kW) dan sistem volt arus (kVa) adalah jelas menunjukkan corak trend penjimatan menggunakan aplikasi VFD. Dengan menganalisisa penggunaan tenaga sebelum dan selepas pelaksanaan pengubahsuaian, keberkesanan VFD dalam mengurangkan penggunaan tenaga yang disahkan. Rancangan Pemantauan dan Pengesahan (M & V) untuk bangunan ini dibuktikan dengan kos operasi HVAC & R dapat dikurangkan sebanyak 7%.

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Alhamdulillah, praise to Allah, with his 'inayah', Finally, I have successfully completed my master project report entitled "Energy Efficiency in Heating Ventilation Air Conditioning and Refrigeration (HVAC & R) Operation Through Variable Frequency Drive (VFD) Application" successfully.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

ECMs	Energy Conservation Measures
HVAC & R	Heating Ventilation Air Conditioning and Refrigeration
M&V	Monitoring & Verification
VFD	Variable Frequency Drive
RDM	Resource Data Management
BMS	Building Management System
LPG	Liquefied Petroleum Gas
GWP	Global Warming Potential
VCR	Vapor Compression Refrigeration
VAR	Vapor Absorption Refrigeration
RT	Refrigerant Ton
FCU	Fan Coil Unit
AHU	Air Handling Unit
AC	Alternating Current
PWM	Pulse Width Modulated
DC	Direct current
kW	Power
kWh	Kilowatt Hours
kVa	Kilovolt Ampere
Kv	Kilovolt

A	Ampere
ACEI	Air Conditioning Energy Index
TNB	Tenaga Nasional Berhad
ROI	Return Of Investment

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, energy audit is crucial in getting the right data for energy efficiency purposes which may reduce greenhouse gases emission. Auditing may come out with ideas to discover which areas that may lead to energy savings in a building or a plant at industries. An energy audit is a procedure the best options for energy conservation to identify the potential energy savings accurately. It is by work out on which changes that should be applied first which is by having a pre-auditing process and then understand the costs and benefits of implementing these changes. Assessments are best carried during the process as part of an ongoing energy management program (Tulsyan et. al., 2013; Krarti et. al., 2016).

Energy Audit is important in order to find a systematic approach to decision-making in the area of energy management. It attempts to balance the total energy inputs with its use and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions. Furthermore, Author concludes that the energy audit is defined as "the verification, monitoring and analysis of the use of energy including submission of a technical report containing recommendations for improving energy efficiency with cost-benefit analysis and an action plan to reduce energy consumption" (Moore et. al., 2001). Thus, those are the objectives of this project report.

Particularly for industries building, the high energy consumptions because of the continuous usage patterns and operation which require substantially variable energy

demands depend on the specialized services provided. Therefore in order to guarantee and maintain satisfactory thermal comfort and indoor air quality, heating and cooling system is very important as well as electricity for Heating Ventilation Air Conditioning and Refrigeration (HVAC & R) system, yield remarkable energy consumptions. From this situation, assessments on energy consumption which includes all the related factors are gathered in a chapter of results for comprehensive analysis. The type of energy audit to be performed for any project depends on certain criteria. One of it is by knowing the function and type of building usage. Then, the energy audit team should know how extensive is actually the final audit is needed, and lastly, they are noted on potential and magnitude of cost reduction desired for an energy audit.

The research survey has been conducted at site cold storage processing and distribution hub for a national retail chain for Giant Company. A total of 140,000 square feet of cold storage processing and distribution center was built on a five-acre site at Bukit Angkat, Kajang, Selangor. The selection of industries building which consists of Air Conditioning for office area and Refrigeration for the cold storage area. Figure 1.1 shows an artist's impression of the GCH Fresh Distribution Centre. Figure 1.2 shows project site area at Lot 5750, Taman Perindustrian Kidamai, 43000 Kajang, Selangor.

Figure 1.1 The GCH Fresh Distribution Centre (www.edgeprop.my, 2016)

Figure 1.2 Project Site Area

1.2 Problem Statement

Heating Ventilation Air Conditioning and Refrigeration (HVAC & R) is a major consumer of energy at the industries building. The total energy consumption of buildings and has the potential opportunities to save energy and achieves energy efficiencies. Thus, monitoring & verification (M&V) initiatives has been implemented in order to measure and evaluate energy consumption patterns, monitoring of how the energy used and record annual energy consumption. Any saving made to the energy consumption of the HVAC & R system will have a significant impact on the building energy cost. Some crucial evaluation and advanced study are needed to provide measures to achieve optimum building energy efficiency. The evaluation is aimed to evaluate current energy is being used efficiently and to identify the potential for energy savings using Variable Frequency Drive (VFD). Based on collecting data and information by Resource Data Management (RDM) software, the total of HVAC & R load is being estimated. RDM is the best solution for energy management and control all aspects of the HVAC & R system throughout industries building. RDM is utilized for remote monitoring and performance strategies by providing the necessary information pertaining to identifying issues, predicting failures, avoiding costly downtime and accurate predictions of capital expenditure and operating costs.

1.3 Research Hypothesis

This research is a survey research strategy that can be utilized for finding estimated to reduce energy costs related to HVAC & R system at the large industries building using VFD application. The study focuses their trend of the saving can be created, energy efficiency potentials and effectiveness of VFD throughout its service life. Another working hypothesis brought up in this research is that the usage of predicting the management operation correctly programmed on the HVAC & R system and fully functioning also helpful on the trend of saving.

1.4 Objectives

The objectives of this project as below:

i. To study on the energy saving using a VFD application in HVAC & R operation.

ii. To study the effectiveness of VFD on electrical properties throughout its service life.

iii. To verify energy performance annually and determine the changes between pre-retrofit and post-retrofit measurement for the building power consumption which can be declared as the energy savings.

1.5 Scopes and Limitation

In this research, it will focus on energy efficiency in HVAC & R system using VFD application. Below is the following scope and limitations of this research:

i. Survey at industries and collect the data on performance HVAC & R operation.
ii. Compare the data with calculation between operation the VFD and without VFD (conventional system).
iii. Analyze the energy saving on HVAC & R system operation.

1.6 Thesis Outline

This thesis has five main chapters. Chapter 1 briefly describes energy audit and their problem statement about the potential saving using VFD application. It also presents the research objectives and scopes. Chapter 2 is about literature review from others researcher related to the derivation of the energy efficiency. The potential way how to reduce energy consumption that is sustainable and energy efficient on that industries building. The research study focuses on HVAC & R using VFD application related to the Building Management System (BMS). The control uses a VFD application building that can reduce energy consumption at the industries building.

Energy efficiency on HVAC & R system in the industries building is important in order to increase the understanding of particular subjects involved in the study. Chapter 3 is involved in the theoretical response of the energy saving study. Literature surveys and site survey at industry side have to conduct before any research or experiment started. After all the important information obtains, the process for data collection can be taken based on the information needed. Start from the formulation calculation of the energy saving the data technical collected related to energy saving. Then, from the technical data collection, perform the data analysis for determining the energy saving.

As the best parameter study from collected data and information by Resource Data Management (RDM) software. The research study focuses on the HVAC & R system operation using with or without VFD application, this study proceeds with the parametric studies of the trend of saving and M&V plan in Chapter 4. The main focus of this study is on the electrical properties of both VFD application and without VFD (constant speed) application. The analysis of data collection consists of power consumption (kWh), system current (A), system power (kW) and system volt-amp (kVa). The highlights and major conclusions drawn from this research together with recommendations for future work are finally presented in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In era globalization, energy consumption is increasing very sharply. Also increases energy costs and the condition is very worst that contribute the global warming potential (GWP) due to greenhouse gas emission. Currently, energy is growing faster because of many factors such as population growth, building development, increasing demand for building services and the level of comforts. Energy consumption of major equipment will be identified. Yang et. al. (2008) has found that the construction of building development is growing faster in the construction industry and it is found that the energy consumption of the office building is higher than residential sectors. Figure 2.1 shows it measured that air conditioning is a major consumption of energy than lighting, lifts and pumps and others by Saidur et. al. (2008).

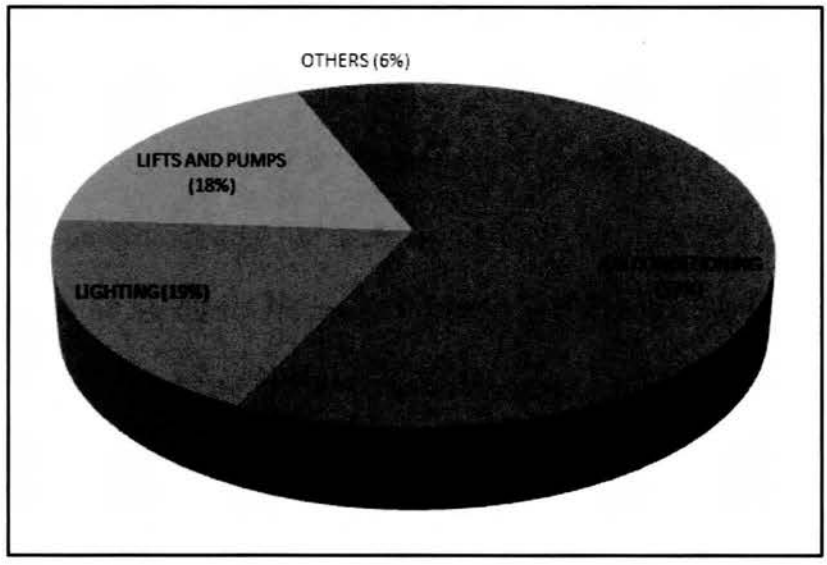

Figure 2.1 Energy consumption at industries building Pie Chart (Saidur et. al., 2008)